DRAFT

U. S. Climate Reference Network (USCRN)

Science and Research Activities and Engineering Support Plan

NWS Facilities at Sterling, VA and Johnstown, PA

May 23, 2002

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{Written in cooperation and collaboration between ATDD, NCDC, NWS, and OSD}
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23 May 2002

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Purpose of the Plan: Describe the short and long range scientific research objectives and plans, experimental procedures, current activities, implementation schedule, and deliverables associated with promoting and supporting science, research, and related programmatic budget and engineering plans and activities associated with the National Intercomparison of NWS and USCRN Sensors **(NINUS)** conducted at the Sterling, VA and Johnstown, PA, NWS test facilities. NINUS is a cooperative effort with NESDIS/NCDC, NESDIS/OSD, NWS, and OAR/ARL/ATDD.

All USCRN Science and Research Activities and Plans will contain a section provided by the systems engineering support personnel at the NESDIS Office of Systems Development (OSD). It is the practice of the USCRN Program that no opportunity will be missed to collect and provide as much data as possible and practical in support of science, research, and engineering goals and objectives.

Extended USCRN Team: The USCRN Program has developed an extended partenership with several different groups. These partners provide subject matter expertise (SME) in the science and research areas and the programmatic planning, budget, engineering and testing, and maintnenace planning and execution. A Memorandum of Understanding (MOU) between the National Climatic Data Center (NCDC) and the Office of Systems Development (OSD) has been signed which provides a general deliniation of roles and responsibilities into two basic categories, science related and system engineering, test, and implementaion activities. NCDC and OSD jointly develop plans, schedules, and budget profiles. Close coordination and cooperation between these various activities are critical to the success of the USCRN Program.

Science and research related activities are managed by the NCDC. SME regarding science and research matters are provided by climate and research people from activities within NOAA, such as the ATDD, NCDC, and OAR, as well as universities and other laboratories and research activities. These SME groups and individuals support the science and research aspects of the program, such as (but not limited to) defining the end-to-end program and network requirements necessary to adequately monitor and evaluate climate change, developing traceable calibration procedures, establishing the criteria for instrument sites, final review of proposed sites, developing the transfer functions between "like" sensors, and other science activities.

OSD provides the USCRN Program with a broad array of engineering and program management expertise. OSD is resonsible for system engineering and maintenance planning assoicated with engineering design based on climate monitoring and evaluation requirments, testing, acquiring systems, siting and installing instrument suites, and establishing initial capability for long-term operations and maintenance.

Collaboration with the National Weather Service (NWS) provides a wealth of knowledge regarding the design, deployment, and m,aintenance of surface observing systems. NWS active participation also provides an excahnge of data and information useful to future enhancements of NWS and USCRN networks.

Background: The U. S. Climate Reference Network (USCRN) is a NOAA-sponsored network and research initiative. During the initial phases of the program (FY 02 and FY 03), a limited number of instrumentation suites will be deployed to test and evaluate the initial configuration of the system in locations across the United States in order to expose the instrumentation to various climate regimes. Eventually, a much larger network of these high quality climate-observing systems will be deployed throughout the nation.

The first and foremost objective of the USCRN instrument suite is to provide benchmark quality air temperature and precipitation measurements free of time-dependent biases. When fully deployed, the USCRN will consist of several hundred stations nationwide at locations selected to capture both the national and regional climate trends and variations for both air temperature and precipitation.

The USCRN Program is currently in the design, testing, and evaluation phase of selecting instruments and an integrated measurement platform. It is essential to understand the performance of these sensors in order to meet the design criteria of the functional requirements document (FRD), and also, where possible, to periodically compare the sensors for temperature and precipitation with others that measure the same parameters.

The long-term success of the USCRN Program depends on a continual evaluation of emerging sensors for air temperature, precipitation, and other secondary meteorological parameters that are important to climate monitoring activities. The current USCRN measurement platform is modular and flexible and can accommodate various types of sensors so that the most accurate and cost-effective technologies can be utilized.

The reference points for all the measurements of air temperature and precipitation are sensor calibrations and procedures that are traceable to well documented standards. *The independent calibration of each USCRN sensor provides a common reference from which all comparisons are to be made. It is this common traceable reference that sets the USCRN apart from all other networks. The same calibration procedures will also be applied to candidate replacement sensors.*

The USCRN Program depends on testing, collection, and analysis of data regarding the performance of potential sensors to be selected and used in the program. The analysis of data and performance of various sensors will be the basis of making final hardware and software decisions for the USCRN. The analysis and data reports will be part of a strong Configuration Management (CM) process to be employed as a means of evaluating and documenting the choice of sensors, sampling protocol, and decisions regarding the system configuration.

Major Goals of USCRN-NWS Applied Science and Research Activities

1. Analysis regarding data quality, data homogeneity, spatial and temporal sampling strategies.

2. Support decisions regarding system design, verification, validation, and engineering.

3. Avoid duplicative efforts in the NWS and USCRN Programs.

4. Ensure transfer functions between sensors (USCRN and NWS sensors) measuring "like" parameters are developed and validated based on accepted scientific methods and make available to researchers in a timely.

5. Ensure routine and continuous evaluation of new (replacement) sensors and techniques in support of the timely replacement of sensors to meet the requirements of the climate research community and accepted climate monitoring practices.

6. Support program management strategies and analyses, such as performance and maintenance issues and costs.

General and Long Range Objectives at the NWS Test Facilities

1. Establish a long-term presence and relationship at the NWS test facilities.

2. Collect, analyze, and provide intercomparison data and develop the transfer functions between sensors (USCRN and NWS network sensors) measuring "like" parameters.

3. Conduct intercomparison testing and evaluation of new NWS and USCRN instruments and techniques. Collect, evaluate, and share data and information on instrument performance that support decisions regarding system design, verification, validation, and engineering.

4. Support initial suitability/feasibility/acceptability analyses regarding data quality, sensor uncertainty, sensor suitability, and bias errors.

5. Identify and support the evaluation of instruments that measure other parameters (i.e., soil temperature, soil moisture, etc.) that may become part of the USCRN and NWS networks.

6. Collect and provide data and information (as part of all applied science and research activities) that contribute to programmatic budget and engineering plans and objectives, such as sensor/equipment performance and maintenance costs, including an assessment of repair/replacement costs that will be incurred over the expected lifetime of various components of the system.

Applied Science and Research – Developing Transfer Functions for Similar Instruments

The primary goal of NINUS is the intercomparison, under the same environmental conditions, of NWS and USCRN precipitation gauges and associated wind shields, temperature sensors, and other instruments that measure "like" parameters. The objective is to develop and validate the specific instrument related transfer functions, biases, between NWS and USCRN sensors that measure the same parameters.

The quantification of these biases will improve the initialization of hydrological models and forecasts. These instrument biases will provide researchers an enhanced capability to utilize NWS network, such as ASOS and COOP, instrument suite measurements for climate monitoring and evaluation purposes. It will provide a broad community of users with a higher degree of confidence in NWS network observations.

NWS Test Facility, Sterling, VA
The Sterling, VA facility has been selected as a site to support common USCRN-NWS applied science and research activities, as well as support to engineering test and design objectives, for the following reasons:

1. Site has a uniform fetch.

2. Infrastructure in place (power, communications) to operate and communicate with data logging equipment and instrumentation.

3. Opportunities exist to leverage parallel monitoring research activities already in place that could provide useful information for evaluating sensor/system performance.

4. Site is an established long-term NWS test bed for assessment of various NWS sensors.

5. The NWS has on-site personnel for maintenance of all instrumentation and grounds.

NWS Test Facility, Johnstown, PA
The Johnstown, VA facility has also been selected as a site to support common USCRN-NWS applied science and research activities, as well as support to engineering test and design objectives. Considerable discussions between NCDC, NWS, and ATDD personnel concluded that the Johnstown, PA facility offers one significant additional advantage over the Sterling site, increased occurrences of wind and frozen prepcipitation events.

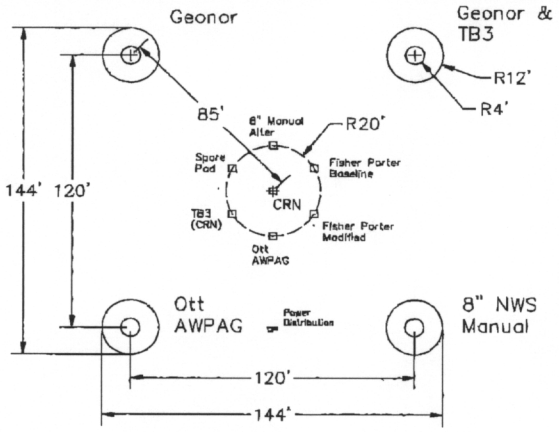
The prinicpal focus of the Johnstown site will be precipitation comparisons. However, the close proximity to an official operating ASOS system provides a unique opportunity to conduct real world intercomparisons.

This second NWS test site provides additional data and information which willl increase the level of confidence of the transfer functions, biases, devleoped between NWS and USCRN sensors.

Photo of the Sterling, VA Facility. The four corners will have a Small Double Fence Intercomparison Reference (SDFIR) w/ Single Alter shiled arrangement for the Geonor precipitation gauge. The center point will be the location of the USCRN insrumentation tower/suite along with the current NWS 1088 hygrothermometer and the recently selected replacement dew point temperature sensor, the Vaisala Model DTS1.

Close-up photo of the Sterling facility illustrating the USCRN tower (center) and the relative location of different precipitation gauge/windshield systems arrayed on a 20 foot radius with respect to the tower.

Figure 1. Initial physical dimensions of the experimental layout at Sterling, VA.



Climate Reference Network
Proposed Layout – Sterling, VA
16 – May – 2002

Initial Instrumentation Configurations

The size of the experimental plot at Sterling, VA was chosen to minimize the distance between measurements of precipitation to reduce spatial variability that is inherent in precipitation events. Another consideration was to ensure that each system had sufficient separation to eliminate any wind shadowing effects.

Initial candidate instruments will include the current configurations of precipitation gauges and associated wind shields and temperature sensors used by the ASOS, COOP, and USCRN networks.

In addition, there will be the ASOS candidate replacement precipitation and wind shield and the proposed secondary gauge for the USCRN. The NWS manual 8" manual gauge will act as the reference gauge. The NWS already has instrument installed at the Sterling and Johnstown test facilities.

Current NWS precipitation guages plan at Sterling, VA include:

NWS standard manual 8" gauge with Single Alter (SA) shield (standard reference gauge)
ASOS Tipping Bucket w/vinyl shield (?)
OTT weighing gauge with Modified Trekyov shield (candidate replacement ASOS gauge)
Fisher-Porter gauge w/data logger
Fisher-Porter gauge w/paper tape recorder

Refer to Figure 1 above for further details at the Sterling, VA test facility.

The physical layout of precipitation gauges described in figure 1 will be used in order to generate the necessary statistics and sample size for the determination of the biases between the different precipitation gauge/wind shield configurations. The physical layout should include a baseline controlled configuration, Gauges with NO wind shield, for the ASOS current and proposed replacement gauge and the USCRN Geonor w/3VWs and the TB3

The current standard USCRN instrument suite, less the GOES transmitter, to include the Geonor w/three vibrating wires (3VW) and the controlled heater device centered inside a Small Double Fence Intercomparison Reference (SDFIR) with a Single Alter (SA) will be installed at Both the Sterling and Johnstown test facilities.

A Eco Harmony TB3 precipitation gauge with heater device and either a Double Alter (DA) or Single Alter (SA) shield will be installed at Johnstown, PA – shield design TBD.

The current precipitation gauge selected by the USCRN is the Geonor equipped with three vibrating wires and a controlled heater device for freezing conditions placed inside the SDFIR w/SA.

A secondary precipitation gauge with a heater device, Eco Harmony, TB3, (tipping bucket) is under evaluation at the Bondville, IL Test Site.

The USCRN is currently evaluating several relative humidity (RH) sensors under a separate applied science study being conducted in Lincoln, NE and Baton Rouge, LA. The current NWS ASOS dew point sensor, Model 1088 hygrothermometer, and the recently selected replacement sensor Vaisala model DTS1, are part of the RH Study.

USCRN Instrument Tower Configuration
There will be one standard USCRN instrumentation suite. A NWS heated sonic anemometer will be added to ensure that there will be wind speed and direction measurements, paricularly useful during freezing or frozen precipitation events. The current standard configured USCRN instrument suite, less the GOES transmitter, will be installed to include the data logger, batteries, lightning suppressor, three temperature sensors (one per mechanically, fan, aspirated shield), wind speed, global solar radiation, and surface (IR) skin temperature sensors, all installed at 1.5m above the surface of the ground.

Calibration Procedures
Sensors will be calibrated in accordance with the NIST traceable procedures adopted by the USCRN for each sensor. NWS will utilize their calibration procedures for the NWS sensors. Each sensor will be calibrated prior to the start of the research project or phase. Calibration checks will be performed as deemed appropriate by the lead research PI. These calibration values will be recorded and become part of the data records for the research project.

Sampling Rate
Sampling and recording procedures will be commensurate with current protocols that are currently in practice for the USCRN instrument suites. The typical sampling rate and processing for sensors used by the USCRN program, except precipitation, are:

A. Air temperature, wind speed, solar radiation, and surface (skin) temperature
Two-second sampling rate (not retained in data logger)
Five-minute average - Average the two-second samples every five minutes
Average the twelve five-minute averages
Standard Deviation computed from the 5-minute data

B. Precipitation - The precipitation gauges will be interrogated for a measure of rainfall at one-minute intervals.

Data Transmission
Data collected from the instrument tower configurations and gauges will be transmitted to an NWS facility via landline, cellular phone, or wireless Internet (TBD by NWS engineers). Data will then be available to ATDD, NCDC, and OSD via the Internet. Additional information collected by the onsite support staff will also be included in the database. This will include the manual observations during precipitation events, maintenance log entries, and any other observations that can be utilized to support OSD USCRN engineering and system design and test plans and activities. Data will be frequently processed and analyzed for interim reports.

Access and Archive of the Data
All data from the research conducted at the Sterling and Johnstown test facilities will be immediately and continuously accessible via the Internet/WWW to ATDD, NCDC, NWS, and OSD. The data will also be available to other USCRN-NWS collaborators. Long-term archive of the data and subsequent analysis and reports will be the responsibility of the NCDC. Data from the research conducted at the Sterling and Johnstown test facilities will be archived at NCDC.

Specific Objectives for FY 02 and FY 03
The following paragraphs describe the immediate targeted USCRN applied science and research objectives for the National Intercomparison of NWS and USCRN Sensors **(NINUS)** activities conducted at Sterling, VA and Johnstown, PA, NWS test facilities.

Precipitation Gauges
Primary Objective: Develop and validate transfer functions (biases) between the NWS and USCRN gauges.

Temperature and RH Sensors
Primary Objective: Develop and validate transfer functions (biases) between the NWS and USCRN temperature sensors.

Secondary Objectives:
1. Determine (if any) differences among measured temperature values from the USCRN and NWS systems for different meteorological conditions.

2. Determine if there is a difference in measured values among shields due to the horizontal distance between the aspirated shields (assumes all shields installed at same height above the ground, 1.5 meters). Observations at installed USCRN sites appears to show a larger difference during the morning and evening transition periods, but not during the more stable mid-periods.

3. The data collected for the evaluation of biases between the USCRN temperature and relative humidity and the NWS systems will will be compared to a concurrent evaluation of these same sensors being conducted in Lincoln, NE and Baton Rouge, LA.

Note: Initial calibration of all gauges and sensors is required at least at the Sterling, VA location is necessary in order to establish a baseline comparative reference point for these specific sensors. It is not required to conduct a calibration of the ASOS sensors at the ASOS operational site in Johnstown, PA.

Analysis of Precipitation Research Activities
The precipitation comparison will be done for various time scales. Precipitation rates will be compared on 1, 5, and 60-minute intervals. In addition, daily precipitation totals (midnight to midnight) will also be compared. The differences among the various shield configurations will be investigated to determine whether or not the observed differences may vary depending on the type of precipitation event (convective vs. frontal), wind speed, and the form of precipitation (frozen vs. liquid).

Collect and analyze data for biases of all precipitation events for all precipitation measurement systems. Transfer functions will be developed between the different precipitation systems for both liquid and solid precipitation. Phase one will end one year from the start date to determine if there is sufficient data to ascertain statistically significant transfer functions between the systems. There will be a coordinated effort with NOAA/NESDIS/OSD to incorporate the appropriate information from phase one into the USCRN master test plan and systems engineering plan.

Analysis of Temperature Sensors Research Activities

To be Completed by Bruce Baker Before Forwarding to OSD

Specify WHO is the LEAD PI/Analyst Responsible for the Development and Validation of the Transfer Functions (insert in both precip and temp analysis sections)

U. S. CLIMATE REFERENCE NETWORK

NWS Contractor Support
Sterling, VA and Johnstown, PA Test Facilities

MAY 18, 2002

1.0 INTRODUCTION

This implementation plan describes the SAIC support intended for U. S. Climate Reference Network (USCRN) sensor comparison testing, a component of Project Plan 1.7.5. Performance of USCRN sensors will be compared to similar ASOS sensors.

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Pressing Enter at the end of an outline sentence will cause the next number to be automatically inserted. Pressing Enter again before any characters will cause the number to move down leaving a blank line above. After typing in phrases or sentences, press Enter to go the next number.

To go to the next division of the outline, press Tab after the Enter which finished a previous phrase or sentence. To move back to the previous division of the outline, press Shift+Tab.

To space a paragraph without inserting an outline number, press Shift+Enter.

2.0 TASKS

2.1 Provide manual weather observation during precipitation events, which occur during normal duty hours (7:00AM - 5:00PM, Monday - Friday) at the Sterling Test Facility.

2.2 Provide test bed output files to NCDC for their analysis efforts. Perform minor maintenance on USCRN computer(s), communications, and/or USCRN sensors at the Sterling Test Facility.

MUST BE RECORDED

In execution of the above tasks, miscellaneous support is necessary. This support includes: general management (i.e., program planning, interaction with NCDC, presentations, technical review, tracking, and reporting); QA; Environmental Compliance, Health and Safety; Training; Administration; Logistics; and Training.

3.0 RESOURCES and COST FIGURES - TBD

TASKS	OPS MAN-HOURS		ENG MAN-HOURS		MAT'L	SHIP	TVL
	REG	OT	REG	OT			
Program Sensor Testing	280		200				
Total							

4.0 SCHEDULE - TBD

A schedule will be determined with NDBC after IWR is approved.

40) 280 = 7 weeks ?

SYSTEM DESIGN, ENGINEERING, AND MASTER TEST PLAN REQUIRMENTS

Contribution from OSD (Dick Reynolds, Short and Associates, May 16, 2002)

Master Test Plan for USCRN

- Prototype (some in SR&DC sensor & algorithm test plan)
- Bondville
- Sensor and algorithm performance (some in SR&DC sensor & algorithm test plan)
- Sensor and algorithm qualification (some in SR&DC sensor & algorithm test plan)
- Site instrument calibration/pre-ship
- Site post-ship/integration/check-out
- Site acceptance/certification
- Network operation
- NCDC processes
  - Network monitor
  - Archive
  - Access
  - Transfer function/site & sensor biases (some in SR&DC sensor & algorithm test plan)

SR & DC Sensor & Algorithm Test Plan

- Sensor & algorithm performance for CRN sys engr & acq activities
  - Data gathering
  - Some analysis as directed by Bradley
  - Some obs required, especially winter weather- Johnstown also
- Sensor biases for NCDC Science Activity
  - Data Gathering
  - No obs expected to be needed
  - No analysis anticipated
- Sensor performance & biases for NWS Co-op and ASOS programs
  - Data gathering
- ???

Typical Test Plan Content

- Scope and purpose
- Useful background info
- What is to be tested – details in appendix
- If a system, description of algorithms and copy of software
- Maintenance requirements and user info
- Interface details
- Test criteria
- What standard(s)
- Time period (at least initial period with TBD follow-on)
- Location(s)- including specific siting requirements

DELIVERABLES

Status Reports: The lead PI and the designated OSD representative will provide a Status Report at each USCRN Program Review.

Deliverables Specific to Precipitation Studies
NLT July 1, 2002 -Deliver Plan of Actions and Milestones (POA&M) for the various tasks.
NLT August 15 2002 - Gauges and wind shield configurations installed and operational
NLT Second Wednesday of each month - Monthly Progress Reports.
NLT December 1, 2002 Preliminary report on the suitability of the Eco Harmony TB3 for consideration as the second precipitation gauge (warm conditions).
NLT March 31, 2003 - Preliminary report on the suitability of the Eco Harmony TB3 for consideration as the second precipitation gauge (cold conditions).
NLT June 30, 2003 – Final Report detailing specific transfer functions (biases), suitability issues, maintenance, and the other analysis as described above.
NLT July 15, 2003 - Deliver all data, descriptions, analysis delivered in format suitable for access via the Internet/WWW.

Deliverables Specific to Temperature/RH Sensors Studies
NLT July 1, 2002 -Deliver Plan of Actions and Milestones (POA&M) for the various tasks.
NLT August 15, 2002 -Temperature probes/aspirated shields configurations installed & operational
NLT Second Wednesday of each month - Monthly Progress Reports.
NLT December 1, 2002 - Preliminary report on the comparative results (warm conditions).
NLT March 31, 2003 - Preliminary report on the comparative results (cold conditions).
NLT June 30, 2003 - Final Report detailing specific transfer functions (biases), suitability issues, maintenance, and the other analysis as described above.
NLT July 15, 2003 - Deliver all data, descriptions, analysis delivered in format suitable for access via the Internet/WWW.

Deliverables Specific to NESDIS OSD Engineering and Test Plans and Activities

To be completed by NESDIS OSD

General Deliverables – All Activities
A Monthly Progress Report (digital in MS Word) is due by the second Wednesday of each calendar month describing the installation, configuration and data collection progress. Included will be descriptions of routine sampling procedures, preliminary analysis of data and statistics relative to the specific objectives of the study, and/or unexpected discoveries.

A Final Report is due within 60 days after the completion of any distinctive phase of the study and at the end of the entire study. These must be in digital form suitable for posting on the Web for on-line access, to include associated documentations, spreadsheets, text files, digital images, graphs, tables, etc.

Points of Contact (POC)
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Tilden Meyers, ATDD, Oak Ridge, TN, (865) 576-1245, 576-1327 (fax), Tilden.Meyers@noaa.gov
Fill In ???????????, OSD, Suitland, MD, ??????
Fill In ???????????, NWS Both HQ and On-site, ????

APPENDIX A

Description of Data Collection and Analysis Techniques and Procedures

To be completed by NCDC, ATDD, and NWS when determined.

Typically done after physical installation completed and data begins to flow.

Requires some preliminary examination of the data.

Includes calibration procedures and resultant calibration values for sensors.

May be several sections for sensors and other devices, i.e. solar panels, etc.

Should specifically refer to potential use of procedures and techniques developed for the objectives at the Bondville Environmental and Atmospheric Research Site (BEARS), Bondville, IL

APPENDIX B

ACRONYMS

AC	Alternating Current
AGL	Above Ground Level
ARL	Air Resources Laboratory
ASOS	Automated Surface Observing System
ATDD	Atmospheric Turbulence and Diffusion Division
AWAPG	All Weather Accumulating Precipitation Gauge
BEARS	Bondville Environmental and Atmospheric Research Site
COOP	Cooperative Observer Program
DA	Double Alter Shield
DC	Direct Current
DTS1	Dew point Temperature Sensor
FDFIR	Full Double Fence Intercomparison Reference
FRD	Functional Requirements Document
GOES ID	GOEStationary satellite IDentification Number
Hz	Hertz
MOU	Memorandum of Understanding
MTBF	Mean Time Between Failures
m	meters
m/s	meters per second
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NINUS	National Intercomparison of NWS and USCRN Sensors
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OAR	Office of Atmospheric Research
OSD	Office of Systems Development
PI	Principal Investigator
POC	Point of Contact
POA&M	Plan of Actions and Milestones
RH	Relative Humidity
SA	Single Alter Shield
SDFIR	Small Double Fence Intercomparison Reference
TB	Tipping Bucket
TBD	To Be Determined
USCRN	United States Climate Reference Network
VW	Vibrating Wire
WWW	Worldwide Web